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Does Design Matter? The Ecological Footprint as a Planning Tool at the Local Level

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ABSTRACT *This paper provides a comparative environmental analysis of three subdivision designs for the same site: an ecovillage, a new-urbanist design and an up-scale estate subdivision. The comparison is based on ecological footprints (EF). Based on built form alone, the higher-density subdivisions resulted in lower EF. Consumption data were limited to the ecovillage, since this is the actual use of the study site, but comparisons were made with regional US averages. The study suggests that consumption contributes more to the overall footprint than built form. Qualitative information was used to explore how consumption is influenced by urban design and self-selection. Despite the challenges associated with data collection and conversion, it is argued that EF has utility for planners and urban designers because it enables assessment of built form from an environmental consumption point of view.*

> The problem of the 21st century is how to live good and just lives within limits, in harmony with the earth and each other. Great cities can rise out of cruelty, deviousness, and a refusal to be bounded. Liveable cities can only be sustained out of humility, compassion, and acceptance of the concept of enough. (Donella Meadows, as cited in Beatley & Manning, 1997, p. 1)

Introduction

Sustainable development is about determining a level of consumption that lies within the capacity of our natural systems to replenish resources and absorb waste. There is growing concern that current levels of consumption and pollution are not sustainable (Borgstrom, 1973; Meadows *et al.*, 1992; Cohen, 1995; Chambers *et al.*, 2000; Christie, 2000). Rather, new ways of living, facilitated by global, national and local changes in economic systems and governance practices, are required.

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From a local governance perspective, Berke & Conroy (2000) note that the planning profession is often criticized for not providing leadership on this important matter. However, recently the planning profession has begun to work with innovative architects, builders, designers and communities to address issues related to sustainability. For example, increasing numbers of developers and builders are recognizing the growing market in the green building sector (Wilson *et al.*, 1998; Mayfield, 2000). Also, proponents of new urban neighbourhood designs are motivated by the potential for such developments to reduce environmental impact and enhance community life (Congress for the New Urbanism, 2000; Lund, 2003). Finally, intentional communities, such as ecovillages, provide a dramatic departure from the large-lot subdivisions that characterize most of North America (McCamant *et al.*, 1994; Fromm, 2000; Meltzer, 2000).

As the market for alternative designs increases, it will be important to develop a better understanding of whether and how these alternatives succeed in reducing environmental impact. The current paper begins to address this question through a comparative analysis of three different subdivision designs—one built (ecovillage), one proposed (up-scale estate homes) and one hypothetical (new urbanist)—for the same site. The primary purpose of the paper is to investigate the degree to which site design, or built form, can influence an individual's environmental impact. The built form is therefore assessed first. Then consumption variables are assessed, some of which may also be influenced by design. A concurrent theme of the paper is design-induced behavioural change, but data limitations prohibit the drawing of conclusion on this issue.

Design, which refers to the broad process of creating built form, is based on the premise articulated by Kevin Lynch that urban form should be designed with a goal (Banerjee & Southworth, 1990). This paper compares how various subdivision designs compare on the goal of sustainability, broadly defined as policies that preserve natural resources for future generations (Barnett, 2003).

The comparison is based on 'ecological footprinting', a tool that was developed by William Rees to assess human impact on the earth's resources (Rees, 1992), and this introduces the second objective of the paper—to critically assess the ecological footprint (EF) as a tool that architects, urban designers and planners might use to evaluate different subdivision proposals. The tool has been applied extensively at international, national and even regional scales; however, the tool's applicability at smaller scales is largely unexplored.

What follows first is a review of the literature on sustainable community design and sustainability assessment tools. Next, the literature on EFs is summarized. The paper then turns to the task of comparing the three community designs in environmental terms. It finishes with comments on the suitability of the EF tool for this type of application.

Research Context

Sustainable Design

The manner in which society designs and builds communities has a profound impact on the quality of the social, economic and environmental systems. Critics are especially concerned with sprawl, which refers to the extension of low-density urban development into rural areas (Calthorpe & Fulton, 2001; Barnett, 2003). Sprawl is associated with a number of ills: high cost of service provision, low levels of social cohesion and environmental degradation. Various alternatives have been proposed (McHarg, 1969; Roseland, 1992; Arendt, 1999). Despite growing awareness, however, few communities have been successful in curbing sprawl (Kelbaugh, 1997; Duany *et al.*, 2000; Pollard, 2001; Burchell *et al.*, 2002).

Amongst the most dramatic of alternative designs are ecovillages, which encourage human-scale settlements that attempt to integrate a supportive social environment with a low-impact lifestyle (Norberg-Hodge, 2002). Participants are motivated by a desire to contest the current trends of globalization that they perceive to be a cause of today's environmental and social problems (Conrad & Withington, 1996; Trainer, 2000). The social and environmental successes of ecovillages in North America, Europe and South Asia have been reported (Bernard & Naylor, 1993; Hu & Wang, 1998; Takeuchi *et al.*, 1998; Canadian Mortgage and Housing Corporation (CMHC), 2000a; Bowers, 2002; Svenson & Jackson, 2002; Kirby, 2003).

However, there are also some challenges and uncertainties. First, the development time is potentially lengthy and the cost relatively high (Fromm, 2000). Second, there are difficulties in forming 'community' (Walker, 1996; Fromm, 2000, Kirby, 2003). Third, the actual level of sustainability achieved has rarely been measured, and only a few sceptics have compared ecovillages to conventional developments in terms of their environmental impacts (Harmaajarvi, 2000). Fourth, many ecovillages are built on greenfield sites that contribute to leapfrog-style sprawl. Finally, the ecovillage lifestyle is a drastic departure from the North American lifestyle, raising questions as to whether it can be considered a mainstream alternative. There is thus a need to look more carefully at intentional communities, especially from an environmental perspective.

More mainstream is the new-urbanist movement, an umbrella term used to refer to various aspects of neo-traditional neighbourhood design and transit-oriented development (Kelbaugh, 1997; Duany *et al.*, 2000; Burchell *et al.*, 2002). Key characteristics of new urbanism are higher density, mixed use, pedestrian orientation, rehabilitation of urban centres, ample public space and diverse housing styles sensitive to local conditions and history. Some of the most prominent new-urbanist developments are Seaside, Florida and Kentlands, Maryland. While such textbook examples of new-urbanist principles applied at the community scale are few in number, new urbanism has drawn increasing attention and partial implementation across North America (Berke *et al.*, 2003; Grant, 2003; Gordon & Vipond, 2005).

While the intended consequences of new-urban designs include decreased automobile use, more active and socially inclusive neighbourhoods, increased sense of community and greater ecological sustainability (Brown & Cropper, 2001), new-urbanist research is still in the early stages, with few conclusive studies of its impact (Fulton, 1996). Some critics argue that new urbanism is simply a new form of sprawl that upholds middle-class lifestyles and promotes homogeneity (Zimmerman, 2001; Leung, 1995). However, some empirical research supports claims of increased sense of community, pedestrian access and social interaction (Brown & Cropper, 2001; Kim & Kaplan, 2004), yet it is acknowledged that personal attitudes and predisposition play a role in creating these differences (Lund, 2003).

Attention is now shifting to whether new urbanism promotes environmental sustainability (Berke, 2002; Congress for the New Urbanism, 2004). Land consumption should be lower due to higher densities and smaller dwelling sizes. However, new-urban designs often incorporate open spaces, making actual land consumption higher than net density figures would suggest. Indeed, the gross density in such developments is often comparable to that of conventional subdivisions (Leung, 1995). Others, however, have found that new-urban developments are more likely than conventional designs to protect and restore sensitive areas, reduce impervious cover and promote environmental protection (Gordon & Tamminga, 2002; Berke *et al.*, 2003). More recent research has considered the demand side and found that new-urbanist subdivisions near Toronto, Canada, have increased densities, but by not nearly as much as would be inferred by an analysis that simply compares the density of the development with that of the surrounding conventional subdivisions (Skaburskis, 2006). This is because residents have moved from higher-density housing to the new-urbanist community, and many plan to eventually move to a single-detached home in a conventional subdivision.

Proponents of new urbanism also claim that their developments can lead to more environmentally sustainable behaviour by decreasing automobile use. Numerous researchers have attempted to understand the influence of urban form on travel behaviour, but available empirical research is at times contradictory, and often inconclusive, in part because of cross-sectional research designs that are not well suited to determining cause and effect (Crane, 1996; Ewing & Cervero, 2001; Rajamani *et al.*, 2003). Studies do indicate, however, that new-urbanist strategies make it easier for those who want to drive less to do so (Fulton, 1996; Handy, 2002). Still, much has yet to be learned about the environmental implications of new urbanism.

While sprawled suburbia remains the norm, the many projects implemented across the US and Canada demonstrate that there is a market for environmentally friendly developments (Wilson *et al.*, 1998; Mayfield, 2000). However, alternative developments of these types often face regulatory barriers. Beatley suggests that public policy is lacking. He characterizes green developments in the US as a "... haphazard, scattered set of buildings and projects ... driven more by enlightened clients and specific designers than by strong public policy" (2000, p. 313). Similarly, others argue that the biggest challenge in expanding the number of alternative developments is the approval process (Duany, 1989; Wilson *et al.*, 1998; Bowers, 2002). Indeed, the American Planning Association (1992, as cited in Wilson *et al.*, 1998) has criticized the legislative framework in many communities for being "... woefully out of step with the times" (p. 193).

As a first step in advocating for change in policy and legislation, local governments and citizens must be given the tools necessary to distinguish the costs and benefits of alternative versus conventional housing, the latter of which typically comprises subdivision-style development on 0.3- to 1.0-acre lots (Burchell & Mukherji, 2003). At present, at both the community and building scale, there is little knowledge of the environmental benefits that alternative designs and technologies can yield (Klunder, 2004). This article provides both comparative data on three different designs and a critical assessment of one evaluation tool that may be used to assess the environmental implications of different forms of development.

Sustainability Assessment

One question addressed in this paper is whether the EF could be a useful tool in planning practice. This question is motivated by the broader issue of the 'best' way to assess sustainability. To begin, we first considered what aspects of environmental sustainability could be addressed through local planning and urban design. Sprawl, associated land consumption and auto dependence are arguably the most challenging planning issues in North American cities. However, individual consumption has been shown to be the dominant component of our society's environmental impact (Spangenberg & Lorek, 2002). Thus, a sustainability assessment tool ought to address questions of both land use and consumptive behaviour. Given the limited influence of the planner/designer on behaviour, a desirable tool also ought to separate consumptive impacts from those due to built form.

A review of the various frameworks available to assess the sustainability of different types of development suggests that there are four general approaches (see, for example, Devuyst *et al.*, 2001). The first focuses on the extent to which resources and ecological functions are protected from development. Assessments of this sort would, for instance, compare how well two designs conserve the most ecologically valuable land. Environmental planning theorists and practitioners such as McHarg (1969) and Hough (1995) have created a theoretical foundation for such designs, and many of these principles are also evident in what is commonly known as eco-system planning (Dramstad *et al.*, 1996; Gordon & Tamminga, 2002). Not surprisingly, 'conservation subdivisions', as proposed by Arendt & Harper (1996), would fare better than most other types of development in such an assessment because of their embodiment of these principles (see, for example, Banerjee and Southworth, 1990; Gordon & Tamminga, 2002; Berke *et al.*, 2003). However, this approach is limited in its ability to deal with the issue of sprawl and the implications of sprawl for transportation patterns and resource consumption more generally.

A second approach to sustainability assessment uses ecosystem indicators to measure how human activities impact the environment. One indicator might relate to species diversity and another to the health of nearby forests. Here, the focus is on assessing changes over time, for example through monitoring programmes, although resultant data also provide an opportunity to compare different developments or regions. The difficulty with these indicators is that they are not easily translated into prescriptive information for planners and developers.

The third type of assessment measures the success of a given development or project against established criteria. The best-known example of this is the US Green Building Council's Leadership in Energy and Environmental Design (LEED) certification process (LEED, 2005). LEED has created sustainability criteria for buildings and is in the process of establishing a neighbourhood certification system. While LEED includes some criteria about site design, it is currently mainly about sustainable architecture and building design.

The fourth type of assessment combines various environmental impacts into a common metric to facilitate comparisons over time and space. Development attributes are considered so as to provide some prescriptive information on how to improve the built form, but so are the consumptive patterns of the residents or businesses occupying the space (Spangenberg & Lorek, 2002). The EF is the best example of this fourth type of assessment tool. However, its attempt to be comprehensive creates challenges associated with data assembly and the translation of various activities into a common metric.

The Ecological Footprint (EF)

The EF translates consumption of various types into the common metric:

> total area of productive land and water ecosystems required to produce the resources that the population consumes and assimilate the wastes that the population produces, wherever on Earth that land and water may be located. (Rees, 2000, p. 371)

EFs quantify humans' overall impact on nature in relation to carrying capacity (Chambers *et al.*, 2000). The average global footprint is 5.4 acres per capita and there are only 4.7 acres available per person based on the biologically productive area divided by the current world population. Hence, we are in a deficit of 0.7 acres per person (Chambers *et al.*, 2000), depleting the earth's natural capital rather than living off nature's interest (Wackernagel & Rees, 1996; Wackernagel & Yount, 1998; Chambers *et al.*, 2000). In calculating the footprint of nations or regions, the different bio-productivities of various land types are taken into account; this is achieved by incorporating equivalency factors, such that the calculated EF is expressed as standardized acres of world-average productivity.

The concept of an EF is now firmly ensconced in the environmental literature and, despite its limitations (see, for example, Gordon & Richardson, 1998; Holmberg *et al.*, 1999; Van den Bergh & Verbruggen, 1999; Deutsch *et al.*, 2000; Herendeen, 2000; Moffatt, 2000; Rapport, 2000), there is considerable support among researchers and environmentalists for the footprint as a clear, unambiguous indicator of human impact on nature that is easily applied (Herendeen, 2000; Moffatt, 2000; Rees, 2000; Templet, 2000). However, most of the work on EFs is at the national or international scale (Wackernagel *et al.*, 2002; Jorgenson, 2003; Senbel *et al.*, 2003). While some attention has been given to individual and small-scale applications (Simmons & Chambers, 1998; Roy & Caird, 2001; Wood & Lenzen, 2003; Holden, 2004), few critical considerations of the EF's potential for sustainability assessment at a smaller scale exist (Wood, 2003). This paper offers one such reflection, by considering its potential for evaluating the relative environmental impact of alternative subdivision designs.

The Three Developments

The first part of this study compares the partial footprint of three different community designs. The site chosen for this comparative work is a 176-acre site in upstate New York's Finger Lakes Region, located just west of downtown Ithaca (Figure 1). The site has already been partially developed as EcoVillage at Ithaca, a grassroots development designed around environmental goals. Thus, the first design being considered is an ecovillage that has been partially built. The second design is based on an alternative plan that was proposed for this site in 1988. Referred to as Rose Hill, this low-density development would have contained primarily one-acre estate lots arranged on a curvilinear road system. Finally, we designed a third, hypothetical alternative for this site, based on neo-traditional planning principles, which we named New Uxbridge.

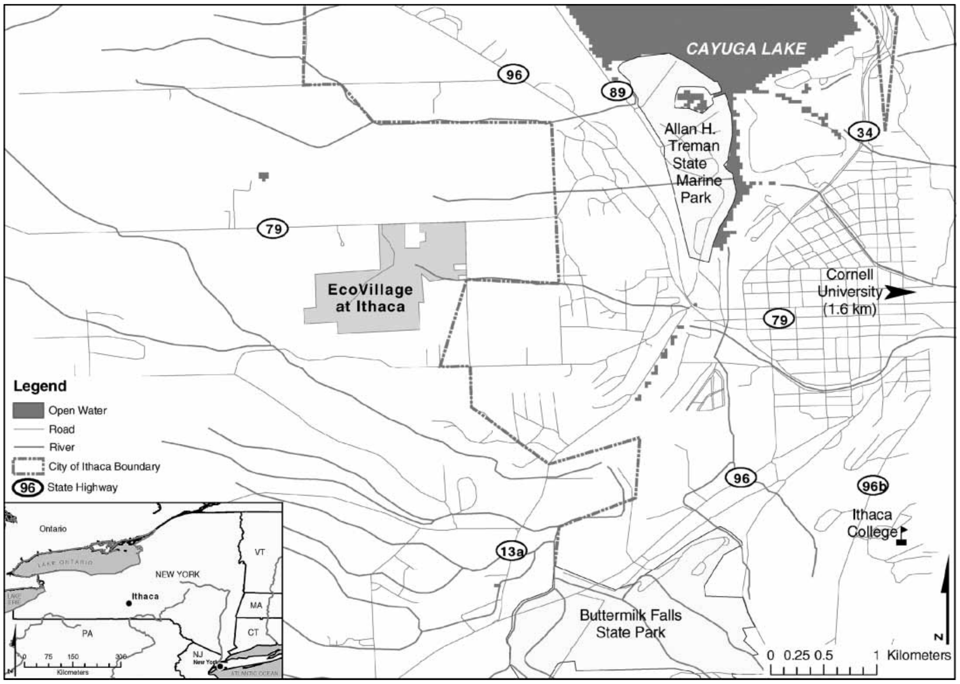

Figure 1. Location map for Ecovillage at Ithaca. Projection: North American Datum 1983. *Sources:* USGS (1997), DMTI Spatial Inc & ESRI Inc. (2000a, b), ESRI Inc. (2000a, b, c), Bureau of Transportation Statistics & ESRI Inc. (2002), USGS & ESRI Inc. (2002), Geographic Data Technology Inc. & ESRI (2004a, b).

In terms of similarities, all three developments contain 150 dwellings with an estimated population of 330, based on an average of 2.2 persons per household (Table 1). Also, it is expected that each would attract a group that is more educated and more affluent than the American average, based on data for EcoVillage at Ithaca, studies of other co-housing (Paiss, 1995), speculations about new urban communities (Leung, 1995), and the up-scale nature of the Rose Hill subdivision. However, personal attitudes and self-selection may play a larger role in influencing environmental impact than demographics. In terms of differences, building designs and residential densities vary significantly across the three developments.

EcoVillage at Ithaca

EcoVillage at Ithaca was designed as a community sensitive to the land on which it was built and the needs of its inhabitants. Initiated in the early 1990s by Joan Bokaer and Liz Walker and purchased in 1992, the site was formerly a dairy farm with most of the land planted in hay, corn and alfalfa. The site also featured woods and wetlands, virtually all of which have been placed into a permanent conservation easement of 55 acres managed by the Finger Lakes Land Trust. Another nine-acre piece of farmland is protected for organic community-supported agriculture that provides fresh produce to members throughout the growing season. Future amenities may include an environmental education centre, biological waste-water treatment centre and restored natural areas.

Table 1. Demographics of study area (US Census Bureau, 2000)

Variable	New York State	Tompkins County, NY	Ithaca City, NY	EcoVillage Area[a]
Total population	18 976 457	96 501	29 006	251
Female to male ratio	1.08	1.04	1.00	1.04
Average age	36.9	33.9	29.1	38.3
Total households	7 060 595	36 464	10 236	97
Persons per household[b]	2.6	2.3	2.1	2.3
Dominant level of education attained	High-school graduate	Graduate/ professional degree	Graduate/ professional degree	Graduate/ professional degree
Average family income	$70 490	$66 014	$55 736	$77 940

[a] Census data from MapPoint for PCensus (US Census Bureau, 2000); since overall demographic data was not available for EcoVillage at Ithaca residents, a polygon was mapped surrounding the site to gather data at the smallest scale at which it became available. All other data in the table are for predefined census areas (US Census Bureau, 2000).
[b] The weighted average of persons per household for Tompkins County and Ithaca City (2.2) was used as the figure for average persons per household for all three developments.

Overall, the community intends to preserve 80% of its area. The site is located approximately 1.5 miles from the City of Ithaca. That proximity to the downtown and access by public transit were also important in site selection (Landesman, 1997; EcoVillage at Ithaca, 2004).

Phase I of EcoVillage at Ithaca (First Resident Group or 'FROG') was completed in 1996, comprising 30 dwellings and a common facility. The homes are tightly clustered. Automobile parking is on the periphery near the access road and the homes are arranged around a pedestrian pathway (Jackson & Svensson, 2002). Figure 2 illustrates the compact design of the community. Phase II (Second Resident Group or 'SONG') homes were completed in 2004. The full design calls for five communities with 30 dwellings in each.

While the site design and housing construction represent a movement toward sustainability in terms of higher densities, conservation developments and energy efficiency, the social dynamics of this and other ecovillages represent an even more radical departure from the norm (Jackson & Svensson, 2002). EcoVillage at Ithaca is a socially motivated village and is modelled after the Scandinavian concept of co-housing. A consensus decision-making process allowed the residents to develop a community before the first house was constructed. Residents share up to three meals a week in the dining room of the common house that also contains common laundry facilities, office spaces, a children's playroom and other shared resources.

The social environment potentially affects environmental impacts through consumption and other behaviour. Meltzer (2000) reports that pro-environmental behaviour and attitudes are encouraged and developed in co-housing communities, and the nature of these communities also fosters the sharing and reduction of resources. For example, Meltzer (2000) found a 26% reduction in the number of washing machines and 29% fewer dryers at 18 co-housing

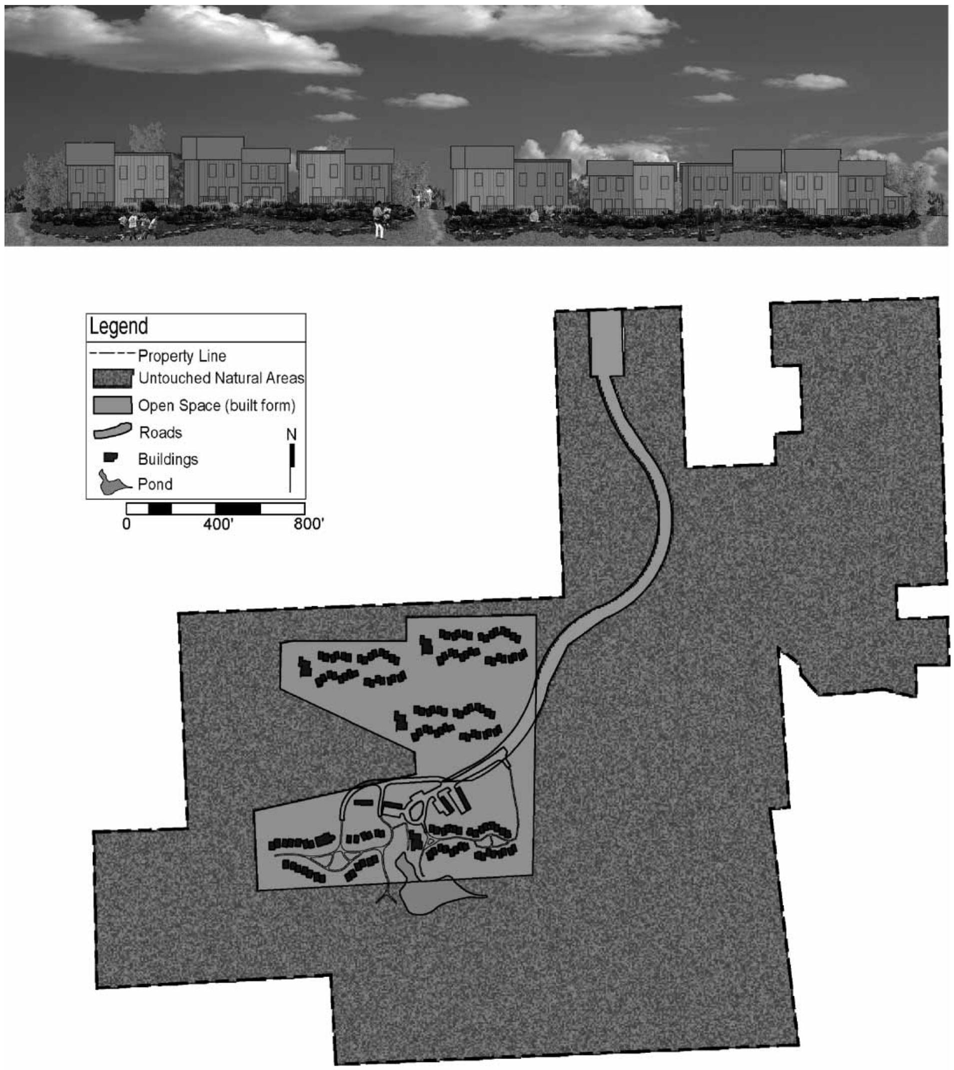

Figure 2. EcoVillage at Ithaca: existing development. *Source*: Map modified from original drawing by TG Miller Engineers & Surveyors (2001).

communities studied. These attributes are expected to translate into a smaller consumptive EF at EcoVillage at Ithaca compared to that for the other two developments.

New Uxbridge

The hypothetical new-urban community of New Uxbridge was designed according to the Charter of The New Urbanism (Congress for the New Urbanism, 2000), and is thus compact with a variety of housing types (Figure 3). Streets are narrow with sidewalks on both sides and medians and on-street parking, where possible, to create pedestrian-friendly spaces that accommodate the car but are not designed solely for it. Public space is in the form of parks and pathways connect private yards. The subdivision is focused around the

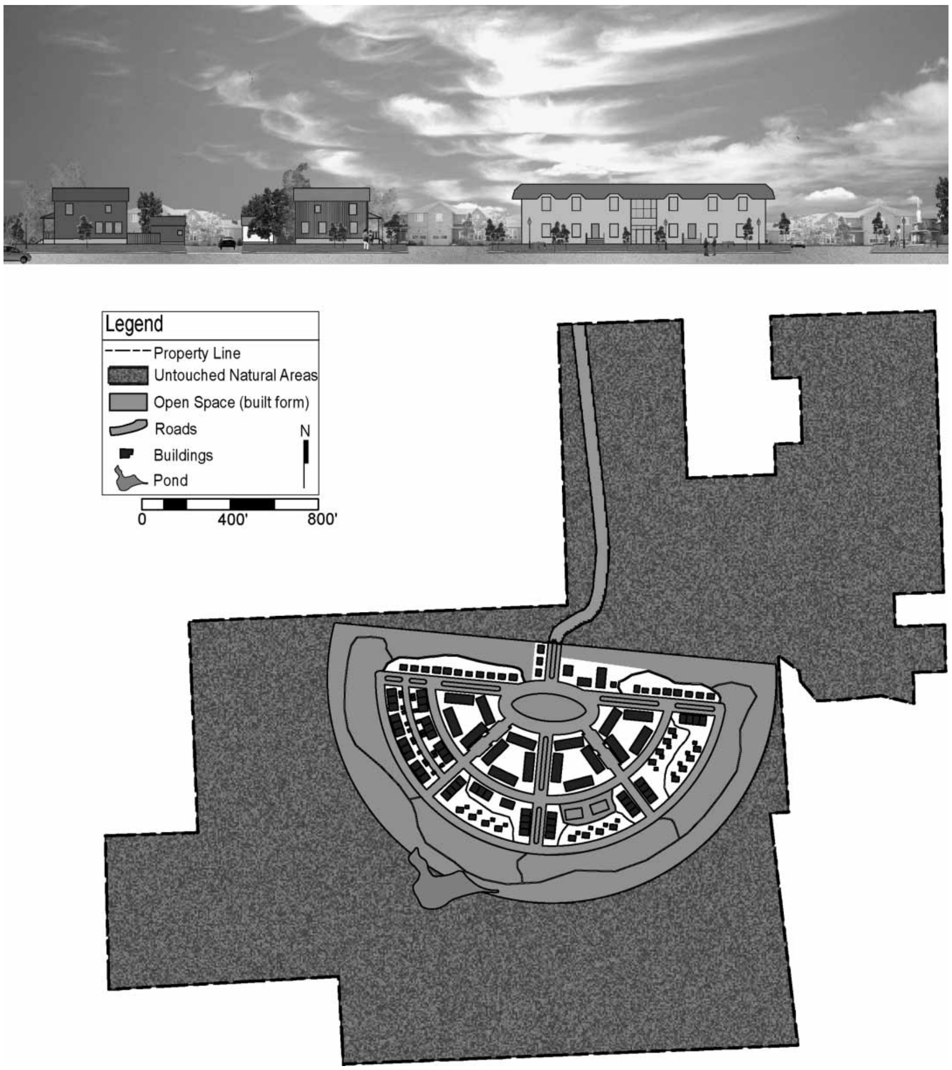

Figure 3. New Uxbridge: hypothetical new-urbanist development.

entrance square in a semi-radial or modified grid-road system (i.e. roads creating a concentric circle about a centre). This system is thought to help create focused suburban areas, distribute traffic evenly on all streets and improve access from private land (Hall & Porterfield, 2001). It also tends to shorten trip distances, especially for walking.

Attempts were made to organize this development as a town with its own urban edges with some mixed use, not solely as a bedroom community—a goal not easily achieved within a small community of 150 dwellings. The suburban centre is within walking distance for all dwellings and contains a telework centre (as described in Johnson, 2003), a daycare centre, coffee shop, gas station/convenience store, bus stop and some retail space. A place of worship, community pool and tennis courts are interspersed within private yards one block away from the centre. A large park with a pond and a network of paths define the suburban edge.

As recommended by the Charter, the New Uxbridge architecture grows from local history and building practices. This includes wood-framed and masonry housing with pitched roofs and dormers (see Town of Ithaca *Design Guidelines* (Town of Ithaca, 2004)). Its streets were designed as public spaces with traditional street lamps, benches, trees, planters and raised cross-walks. Garage access from alleys removes cars from the front of the house on some of the streets. In other instances, on-street parking provides a barrier between traffic and pedestrians. The subdivision contains 16 single-family detached units with separate garages to the side of the house, 22 single-family detached dwellings with garages in front of the house, 21 town-house units with separate alley garages, 27 town houses with driveway garages out front and 64 large apartment units for families arranged around a courtyard in four groups of four two-storey buildings with on-street parking.

Rose Hill

The Rose Hill development, which filed for bankruptcy in the early 1990s, was first proposed in 1988. Indeed, EcoVillage at Ithaca purchased this land from the developer, who had planned 150 dwellings, most on one-acre lots (Landesman, 1997). Figure 4 shows the proposed Rose Hill plan that included 50 town houses and 100 single-family residences occupying virtually the entire site. The Rose Hill subdivision would have been an up-scale suburban neighbourhood with low-density residential use and public open space mainly in the form of remnants on the edge of the development.

Research Methods

A number of primary and secondary data sources were utilized for the research. Because EcoVillage at Ithaca is partially developed, it was possible to assemble physical design, construction and behaviour-based information. Site visits were made by Johnson in 1998, who conducted key informant interviews with residents, and Whitfield (2001), who surveyed residents, consulted with local planning officials and participated in numerous community meetings and workshops. Short surveys, prior studies conducted at EcoVillage at Ithaca and government publications were used to assemble the data necessary to conduct the EF analysis for this site. The main use of resident interviews was to inform our understanding of the interactions between physical design and environmental behaviour. For the other sites, physical design data were extracted from site-plan drawings and US average data were used as a first approximation for other types of consumption.

EF Calculations

This analysis builds on the work done by Wackernagel *et al.* (2003) by applying their spreadsheet to estimate the EF for three different neighbourhood types—the ecovillage, a new-urbanist neighbourhood and a low-density development. Two sets of calculations are provided. The first provides estimates of the aggregate EF for the three designs based only on the physical parameters of each development. The second combines information on the physical parameters with selected consumption data in order to derive a partial estimate of the per-capita EF for each

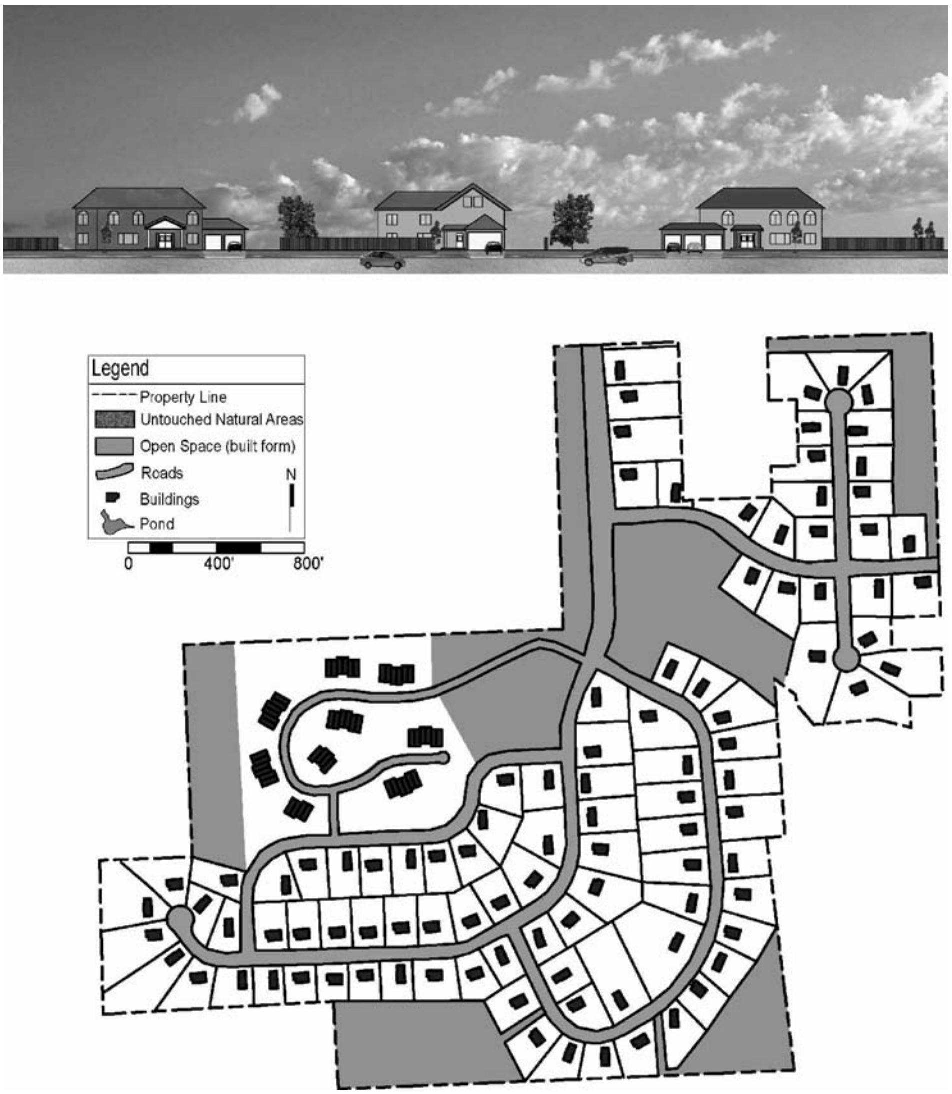

Figure 4. Rose Hill: defunct conventional subdivision development. *Source:* Map modified from original drawing by Hunt Engineers & Architects (1998).

of the three alternatives. Data limitations precluded the inclusion of some behavioural categories such as food consumed in restaurants and air travel, but the categories that are included account for 59% of the average American footprint (see Wackernagel *et al.*, 2003).

The physical parameters for the aggregate footprint calculation include the amount of built-up land and the consumption of materials in developing these lands (translated into the use of forests and fossil energy). The total built-up land was based on the space used for roads, buildings, parking, paths, private yards and open areas in the form of parks or remnants at the edge of developments; the latter were counted as built-up land because they were designated for human use. Undeveloped natural areas did not contribute to the EF, and all built-up land types were assigned the same bio-capacity. The latter decision ignores the possibility that some open spaces may require watering or maintenance, but since the focus is on comparative values the net effect should be minimal.

The consumption of building materials was based primarily on building sizes, as gleaned from site plans. In the case of EcoVillage at Ithaca, site plans were supplemented with interviews with the construction and development managers. Given that the design of this village was intended to reduce environmental impacts, prospective residents subjected each material to a process similar to life-cycle analysis. Once this was completed, and considering cost differences, residents then decided whether to use environmentally friendly products. Two decisions, in particular, were deemed to be important for the current assessment; these were the wood products used for wall framing and the decision to install triple-glazed windows, both of which would translate into a higher R-value (i.e. resistance value, the standard method of measuring the insulating properties of a material). It was determined that double walls added about 10% to the amount of wood used in the construction of homes. The EF spreadsheet for EcoVillage at Ithaca was adjusted upwards to account for the increased wood in the construction. However, adjustment of the EF to account for triple-glazed windows was not done, as the steps necessary to modify the EF were outside the scope of this study.

The second comparison focuses on per-capita consumption. In this case, three out of the six physical parameters listed above—the buildings, parking areas and private yards—were included. The EF calculations for these components were added and then divided by the number of residents (330) to achieve a partial EF at the individual level. To this were added consumption data. In the case of EcoVillage at Ithaca, data came from prior surveys conducted at the site. For the other two developments, average US regional EFs were used.

Key informant interviews with community members during the first site visit to EcoVillage at Ithaca assisted in developing the data collection strategy. It was clear from that visit that an in-depth survey would not work because of survey fatigue by residents, besides which considerable data already existed for estimating the EF. The decision was made to focus on food consumption, automobile use and utilities (residential energy use and water consumption), since these categories account for a large proportion of most households' EF and also because of available data.

Three data sources provided information on the food component. First, data were obtained from an earlier nutritional survey conducted by a Cornell student in 1996 (Bloomfield, 1997). Twenty-two of the community's 30 households at the time had participated in the study that included a survey of food purchase/consumption by major food categories. Additional information was obtained from a local retail food co-operative that maintains a computer transaction record of all members' purchases. Thirteen residents authorized the local food co-operative, GreenStar, to provide the authors with the relevant data. GreenStar's point-of-sale system produced a history of a member's purchases associated with the member's number. Finally, grocery receipts and meal attendance records for the common house meals, where residents dine together for up to 24 meals a month, were obtained for the year 2000. These data sources provided a representative sample of residents' food intake both in the common house and within their own homes.

Transportation and utility use data were also estimated for EcoVillage. The number of automobiles by household was obtained from interview data and information provided by a resident who was compiling transportation data to report on energy savings at the village. These data included information on the number of employed residents and the locations of their employment, as well as vehicle make, model and year. Fuel consumption was based on statistical data provided by the US Department of Energy (DOE) and the US Department of Transportation. Finally, natural gas, electricity and water consumption were obtained for one year from detailed records kept by the community for all residential units.

Results

Site-level Comparison Based only on the Built Form

The physical designs of the three developments vary considerably, as summarized in Table 2. Both gross and net densities are highest for EcoVillage at Ithaca and lowest for the estate-style development of Rose Hill. The degree of difference is worth noting: gross densities of 5.7, 3.2 and 0.9 and net densities of 49.6, 10.5 and 1.2 dwellings per acre for EcoVillage, New Uxbridge and Rose Hill, respectively. Other notable differences, not included in Table 2 but illustrated in Figures 2–4, are the lands devoted to parking, private yards and roads—which are lowest for EcoVillage and highest for Rose Hill. Finally, it is important to consider the percentage of land that is left as undeveloped open space, which is highest for EcoVillage (85%), only slightly lower for New Uxbridge (73%), but negligible for Rose Hill.

For all three designs, densities are low relative to a number of other comparable developments. For example, the average gross density of 41 co-housing-based ecovillages in the US and three in Canada was calculated to be 11 dwelling units per acre (Fromm, 2000), which is approximately double that of EcoVillage Ithaca. Similarly, new-urbanist developments throughout North America have gross densities ranging from 4 to 12 units per acre (Leung, 2003; Civitas, 2005; Gordon & Vipond, 2005), whereas the proposed New Uxbridge development has a gross density of 3.2 units per acre. Finally, net densities of conventional subdivisions generally range from 1 to 5 units per acre (Leung, 2003; Gordon & Vipond, 2005), whereas for the Rose Hill plan the value was 1.2. The lower densities in our case study result from protected natural areas in the case of EcoVillage at Ithaca, parkland in the case of New Uxbridge and large lots in the case of Rose Hill. The implication for the results is that the EF due to design may be overestimated, but the comparability of results for the three designs should not be compromised.

The land uses are summarized in Figures 5 and 6. EcoVillage at Ithaca and Rose Hill provide the greatest contrast in land-use patterns. In 1996, when EcoVillage was opening, co-founder Liz Walker emphasized that difference:

> This developer [Rose Hill] had planned a typical suburban development . . . which would have completely covered the site with roads, garages and houses. He left 10 percent of the site for open space, as mandated by the Town of Ithaca. Thus, by developing EcoVillage, we were in effect preserving green space and farmland that would otherwise have been paved over. (Walker, 1996, p. 42; see also Vizard, 1997)

Table 2. Development characteristics of EcoVillage, New Uxbridge and Rose Hill

Category	EcoVillage at Ithaca	New Uxbridge	Rose Hill
Description	Built and designed by its residents; 150 units projected; 60 units completed in 2001, 30 units completed in 2004; 26.4 acres of built land on 176-acre site	Designed by the authors; 150 units proposed; 47.5 acres of built land on 176-acre site	Proposed defunct development; 150 units proposed; 176 acres of built land
Character	Co-housing units; shared community centre; car-free community; path network connects units; environmental technology incorporated in design; almost all of site is public space; some mixed use	Traditional neighbourhood design; small private lots; style draws from prevailing housing stock in Ithaca; front porches, alleyways, on-street parking; ample public space; some mixed use; interconnecting street network	Conventional suburban neighbourhood design; large private lots and dwellings; long driveways; wide roads; single-use development
Land-use pattern	One housing type, but variety of sizes and construction types (e.g. straw-bale versus regular insulation)	Wide variety of housing types	Two housing types only
Average gross[a] density	5.7 dwellings per acre	3.2 dwellings per acre	0.9 dwellings per acre
Average net[b] density	49.6 dwellings per acre[c]	10.5 dwellings per acre	1.2 dwellings per acre
Public open space	17.6 acres or 67% of built land is open space; 149.6 acres or 85% of site is undeveloped natural areas	25.7 acres or 53% of built land is open space; 128.6 acres or 73% of site is undeveloped natural areas	25.6 acres or 15% of built land is open space; all open space is interspersed within development or left as remnants, thus no land is counted as undeveloped natural areas

[a] Gross density equals the number of dwellings per acre of built form. Built form was assumed to include any public open space within the subdivision or immediately surrounding it. Natural areas left undeveloped are not included as built form. Note that the density for the overall site is equal for all three developments.

[b] Net density equals the number of dwellings per acre of residential land area (i.e. acreage of private lots).

[c] Because of the nature of the co-housing development, only a small portion of space is private residential lots whereas the majority of open space is shared public space. This inflates the net density figure.

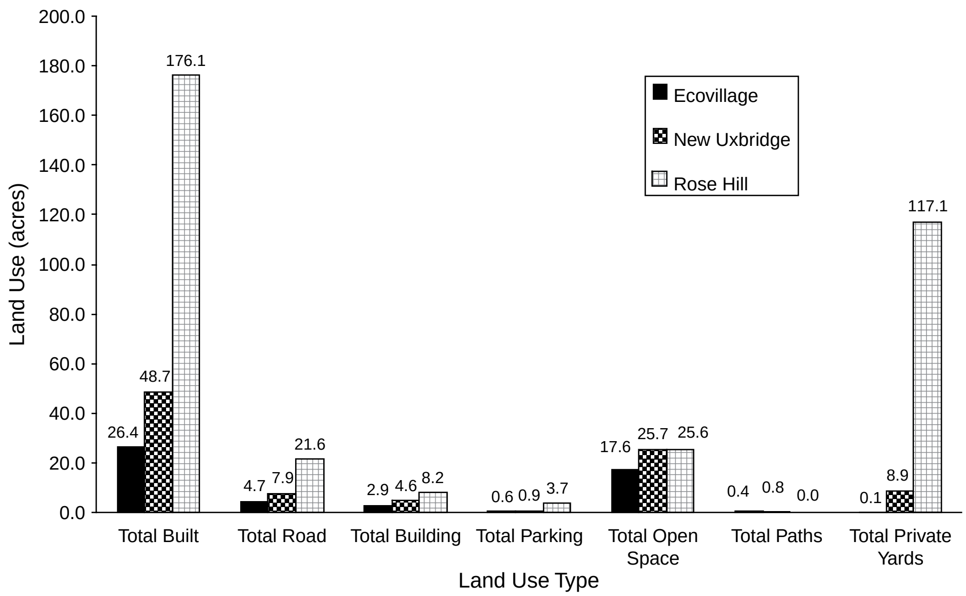

Figure 5. Land-use comparison: three alternative subdivision designs.

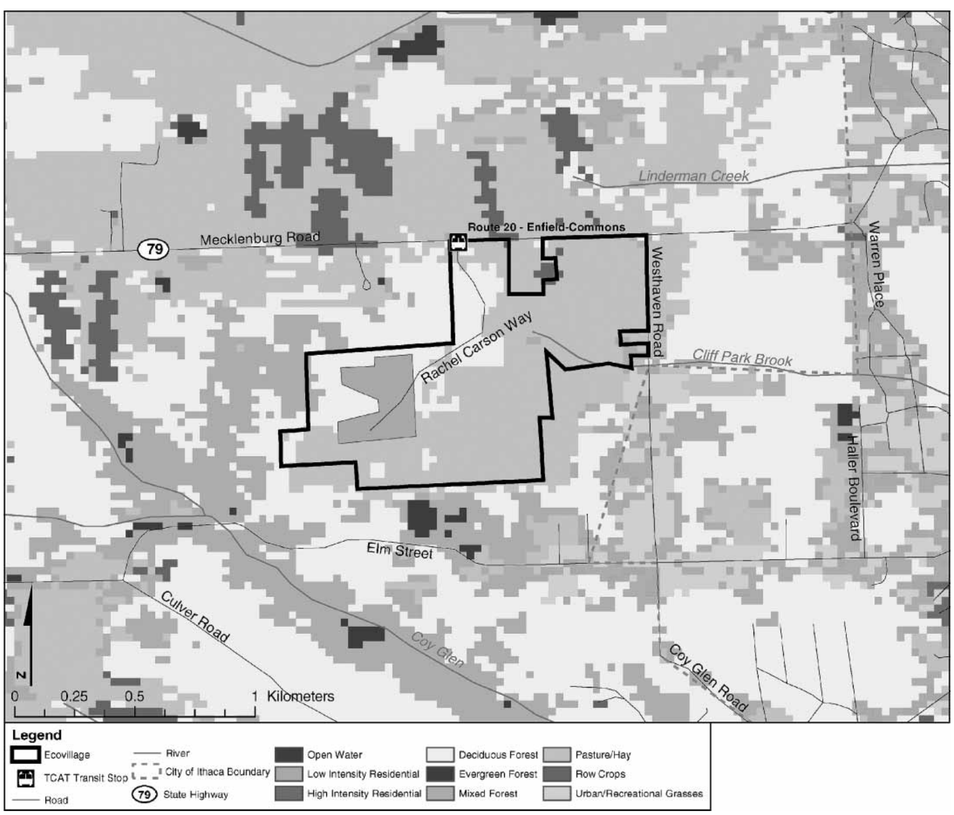

Figure 6. EcoVillage at Ithaca, land-use map. Projection: North American Datum 1983. *Sources:* USGS (1997), ESRI Inc. (2000b), Bureau of Transportation Statistics & ESRI Inc. (2002), Geographic Data Technology Inc. & ESRI (2004b).

As shown in Figure 6, the EcoVillage design preserves lands in a way that allows linkages of different ecosystems to remain intact; the on-site creek, farmland and woodlands are still connected. The Rose Hill subdivision would have acted like a large barrier to what are otherwise mainly large tracts of agricultural and wooded land in the surrounding area (compare Figures 4 and 6). While taking up more land than EcoVillage, New Uxbridge still allows some preservation of environmental linkages (compare Figures 3 and 6). The importance of protecting ecosystem linkages is explored by McHarg (1969) and Hough (1995), but is not part of an EF investigation.

In terms of site details, once EcoVillage at Ithaca is fully developed, the total developed area will be 26.4 acres, consisting of 150 two-storey housing units ranging from 900 to 1650 square feet for an approximate total of 3.0 acres being used for buildings (including common buildings). Only 0.1 acres will be used for private yards, 4.7 acres for roads, 0.6 acres for parking (parking lot at edge of subdivision), 0.4 acres for pathways and 17.6 acres for public open space.

The developed area of New Uxbridge would occupy an area that is nearly twice that of EcoVillage (48.8 acres), with more space being devoted to buildings (4.6 acres). Residential units would range in size and include:

- 1512-square-foot single-family detached houses (two stories) with a 378-square-foot separate garage;
- 1183.5-square-foot single-family detached houses (two stories including attached garage);
- 1386-square-foot row houses (two stories) with a 378-square-foot separate garage on back-lane;
- 1275-square-foot row houses (two storeys including attached garage);
- 1500-square-foot apartments (plus common areas).

Private yards, roads and parking (both on-street and driveway) would also occupy more land in New Uxbridge than is the case in EcoVillage at Ithaca. Streets would have a right of way of 48 feet with 10-foot-wide lanes and 5 feet of sidewalk. The right of way would increase to 54 feet when there were central boulevards and to 57 feet with on-street parking. Finally, pedestrian paths and public open spaces would also be more extensive in New Uxbridge than in EcoVillage, although in both cases most of the site would remain undeveloped.

The development of Rose Hill stands in contrast to both of the above designs in terms of its use of the site. For Rose Hill, the entire 176.1-acre site would have been developed, with 8.2 acres being used for buildings, a value nearly three times that of EcoVillage at Ithaca. Residential units were estimated to be on average 2625 square feet for the 100 single-family dwellings (including garage) and 1875 square feet for the 50 town houses. The value for private yards would be dramatically higher at 117 acres compared to New Uxbridge's 8.9 acres and EcoVillage at Ithaca's 0.1 acres. Roads and parking areas, too, would also be higher in Rose Hill than in the two alternatives, by factors of 3 to 6. In terms of details, the right of way was estimated to be 60 feet with 18-foot-wide lanes and 3-foot sidewalks. Driveways averaged 21 feet wide and 50 feet in length.

Table 3 illustrates how the land areas from Figure 5 translate into EF values. As expected, the more compact designs translate into a lower EF. The EcoVillage subdivision has the lowest footprint at 385.4 acres, followed by the new-urbanist design with an EF of 585.1 acres. Rose Hill, with its low-density design, would

Table 3. Ecological footprint values (acres): three developments

	EcoVillage at Ithaca	Percentage of total footprint	New Uxbridge	Percentage of total footprint	Rose Hill	Percentage of total footprint
Roads	11.2	2.9	18.7	3.2	51.5	4
Building	353.8	91.8	515.6	88.1	908.8	71.4
Parking	1.5	0.4	2.1	0.4	8.7	0.7
Open space	17.6	4.6	25.7	4.4	25.6	2
Paths	1	0.3	1.9	0.3	0.1	0.01
Private yards	0.3	0.1	21.1	3.6	278.4	21.9
Total built form EF	385.4	100	585.1	100	1273.1	100
Average EF built form[a]	1.2	N/A	1.8	N/A	3.8	N/A

[a] Assumes 2.2 people per dwelling unit for each of the 150 units in each subdivision (i.e. divide 'built form EF' by 330).

have an EF of 1273.1 acres. Of particular note is that the Rose Hill design requires a hypothetical area to support consumption that is over seven times the size of the entire site.

The components that contribute to the large overall differences warrant some comment. In all three cases, the buildings themselves account for the majority of the EF—from 71.4% for Rose Hill to 88.1 and 91.8% for New Uxbridge and EcoVillage at Ithaca, respectively. However, the absolute EF values vary substantially—from 353.8 acres from the compact EcoVillage design to 515.6 acres for the new-urbanist plan to 908.8 acres for the large homes in Rose Hill. In absolute terms, other than buildings, the largest difference is for private yards, which dominate the Rose Hill landscape. For Rose Hill, such yards account for more than one-fifth of the calculated EF, whereas in the other two developments the percentages are 3.6 and 0.1.

On another note, it is possible to use some of the data assembled for the EF in order to explore other environmental issues related to site development. The issue of surface runoff has salience because of its association with storm-water management, surface erosion and water pollution. Green designs often try to reduce the amount of impermeable surface by protecting or creating natural spaces or adopting alternative ground covers, such as using interlocking stones for parking lots. Based on data assembled for the EF analysis, it is clear that the amount of land used for roads and parking is considerably higher for Rose Hill than for the other two designs; the values are 5.3, 8.8 and 25.3 acres for EcoVillage at Ithaca, New Uxbridge and Rose Hill, respectively.

Per-capita Comparison Based on Selected Residential and Consumption Components

This next section discusses the individual EF values as calculated from the three aspects of the built form that relate most closely to individual households (buildings, parking and private yards) as well as three behavioural categories including residential utilities (natural gas for heating, electricity and water), food consumption and automobile travel.

Table 4. Per-capita EF for built form (building, parking and private yards) by various dwelling and yard sizes

Development	Dwelling size (rounded average, square feet)	Private yard size (rounded average, square feet)	Ecological footprint (per capita, acres)
EcoVillage at Ithaca	922	36	1.2
	1100	36	1.4
	1350	36	1.7
	1650	36	2.1
New Uxbridge	1100	4000	1.4
	1300	1000	1.5
	2000	100	2.3
Rose Hill	1800	29 000	2.8
	2600	37 000	3.9

The EF components for the built form are shown in Table 4. As shown here, per-capita values for housing range from 1.2 acres for the 922-square-foot units at EcoVillage to 3.9 acres for the 2600-square-foot homes in Rose Hill. Depending on the dwelling size, there is some overlap between homes in EcoVillage at Ithaca and New Uxbridge and between those in New Uxbridge and Rose Hill; however, overall the average per-capita EF from the housing component is lowest for EcoVillage (1.6 acres), slightly higher for New Uxbridge (1.7 acres) and considerably higher for Rose Hill (3.3 acres). These findings are consistent with the argument by Wackernagel & Rees (1996), Walker & Rees (1997) and Chambers *et al.* (2000) that cities have an opportunity to reduce their environmental impact by encouraging higher densities.

The next focus was on residential utilities. Natural gas is used to heat the buildings at EcoVillage at Ithaca. Between 1998 and 2000, EcoVillage at Ithaca averaged 15.7 CCF (100 cubic feet) per person per month, whereas the average American in the Northeast Census Region used 27 CCF in 1997 (DOE, 2000a). The national average is slightly lower at 26 CCF per capita. Electricity consumption is also lower at EcoVillage at Ithaca (138 kWh per month based on records from 1999 to 2000) compared to the averages for the Northeast and the entire US at 232 and 327 kWh per month, respectively (DOE, 2000a). Finally, water consumption for EcoVillage residents averaged 1000 gallons per person per month between 1998 and 2000. The United States Geological Society (USGS) reported that the state of New York used 2010 million gallons per day in 1990 or 3400 gallons per person per month, i.e. three times that of the residents of EcoVillage (USGS, 1999). More recent data from the Bolton Point Water Plant, which supplies the drinking water for the Town of Ithaca, suggest that the average home uses 2300 gallons per person per month (Bolton Point Water Plant, pers. comm., 24 July 2001). Figure 7 illustrates these data. For EcoVillage Ithaca, the value for this component of the EF is 2.3 acres.

A variety of data sources were used to piece together food consumption, and these data reveal a dramatic difference between EcoVillage residents and average American eating patterns. EcoVillage at Ithaca residents reported eating only one-sixth as much meat (2.5 lbs of pork, beef, chicken, turkey and fish) as the American average (16 lbs). Eggs, fruits and vegetables, and milk and yogurt were also consumed in lower quantities by residents of EcoVillage. More specifically,

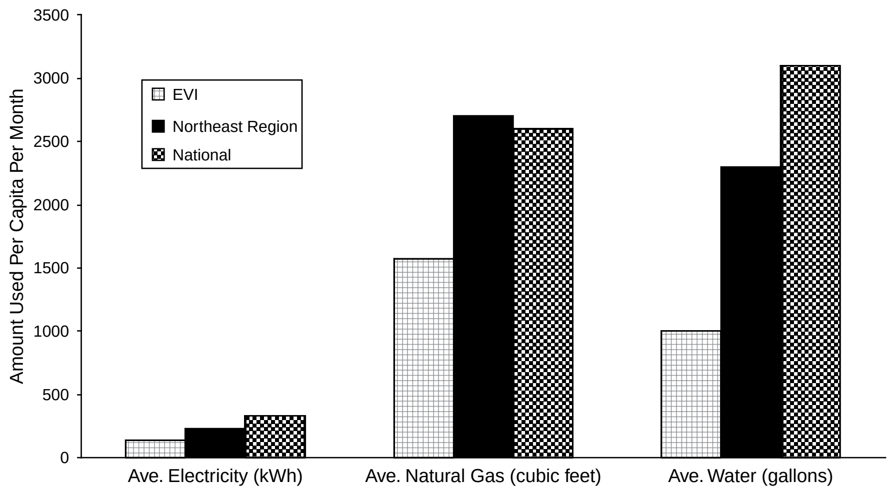

Figure 7. Energy/water consumption for EcoVillage at Ithaca (EVI) and the average American.

compared to the American average, EcoVillage residents consumed 66.7% (15.3 eggs), 4.5% (37.2 lbs) and 95.5% (8.5 quarts) of these three food groups, respectively. In contrast, these residents consumed 166.7% more cheese and butter (4.5 lbs) and 171.4% more dry beans (2.4 lbs) than the average American.

Translating the food data into an EF value required that some assumptions be made as to the level of organic and local content. In order to explore the sensitivity of the results to the assumption made, three EF calculations were made: one for low organic/local content, one for average organic/local content and one for high organic/local content. The resultant values for this component of the EF were 3.9, 3.4 and 2.9 acres, respectively.

The average fuel consumption per vehicle for the EcoVillage residents who participated in the survey ranged from 6.6 to 90 gallons per month, with an average of 32 gallons per vehicle per month. This is much lower than the Northeast Region average of 45 gallons per vehicle per month (DOE, 2000a, b, c). Part of the explanation would seem to lie in the work location of residents. We know from other data that 26% of employed residents worked on site, either in the common house or from a residence-based business (Whitfield, 2001). Considering both the travel distances and the vehicle fleet of EcoVillage residents, the EF calculation for automobile transportation was estimated at 3.2 acres.

The EF values from food, transportation and utilities were combined in order to derive a composite partial EF. The value for EcoVillage residents was 8.9 acres, assuming average organic and local content in groceries purchased: 2.3 acres for utilities, 3.4 acres for food and 3.2 acres for transportation. The regional average for these three categories is 15.3 acres.

Results for the housing and behavioural categories of the EF are displayed in Table 5. As shown here, EcoVillage is estimated to produces a partial footprint of between 6.4 and 14.0 acres per person, depending on dwelling size and food purchases. We also produced comparable calculations for the new urban and suburban developments of New Uxbridge and Rose Hill. Assuming that residents of these developments consume food, transportation and utilities at a rate

Table 5. Partial EF for three urban designs (acres)

Subdivision	Housing EF[a]	Food, transportation and utilities EF	Combined EF
EcoVillage at Ithaca	Minimum[b] (1.2)	5.2	6.4
	Average (1.6)	8.9	10.5
	Maximum (2.1)	11.9	14
New Uxbridge with average regional consumption	Minimum (1.4)	15.3	16.7
	Average (1.7)	15.3	17.0
	Maximum (2.3)	15.3	17.6
Rose Hill with average regional consumption	Minimum (2.8)	15.3	18.1
	Average (3.3)	15.3	18.6
	Maximum (3.9)	15.3	19.2

[a] Includes building, parking, private yards.
[b] Minimum, average and maximum EF for housing from Table 4.

equivalent to the US regional average, the EF values work out to 16.7–17.6 and 18.1–19.2 acres for New Uxbridge and Rose Hill, respectively.

Two issues are particularly well illustrated by the above comparisons. The first is that more compact developments are likely to result in substantially lower environmental impact than the estate-style developments that have proliferated throughout North America during the past half century, entirely because of differences in the built form. The second is that behavioural patterns are as important, or possibly more important, than physical parameters, which leads to the next section where we attempt to partially disentangle the effects of design-induced behavioural changes from those of individual preferences and value systems.

Toward an Understanding of Environmental Behaviour

> Environmental ethic? I think I was born with it! (EcoVillage at Ithaca resident)

While the above results show that EcoVillage residents had lower EF values for food, transportation and utilities than the regional average, the question remains whether this was facilitated by the physical design of the village and/or social practices in the village. The alternative explanation is that differences are due to self-selection (i.e. prior environmental behaviour existed). As the following evidence reveals, a combination of all three factors appears to have resulted in the lower consumption values.

Some of the design features at EcoVillage at Ithaca that helped residents conserve water include smaller, well-insulated buildings, low-flow toilets and faucets and natural landscaping with reduced or no lawns. Indeed, it would appear that many differences between EcoVillage Ithaca and the regional average for the utility component of the EF are due to design.

Decreases in transportation were mainly achieved through working from home, which is partly facilitated by design (i.e. providing office space in the common house), but also depends on residents' work arrangements and motivations. The interviews revealed that practices adopted by the community have also facilitated lower car use. First, the EcoVillage community design prohibits automobile travel within the subdivision. Second, and more importantly, the nature of the co-housing community encourages car pooling and communal activities within the village that potentially reduce travel. As such, it is difficult to know how much of the savings in transportation can be attributable to design, but it seems reasonable to suggest that design plays a role.

The lower food impact at Ecovillage Ithaca appears to be partially due to the co-housing practice of sharing meals. However, the interviews revealed that a number of residents had been vegetarian or practised low-impact food consumption (e.g. purchasing local/organic foods) before moving to EcoVillage at Ithaca, illustrating some degree of self-selection. Most participants also acknowledged their commitment to environmentally oriented activities and/or concerns prior to moving here. Indeed, environmental and social attitudes were dominant themes in both our interviews and other studies (Kirby, 2003). What appears to have happened here is that the physical design and community sense of spirit together have provided new opportunities for and/or removed old barriers that interfered with environmentally responsible behaviour, so again design appears to play a role.

Interestingly, for most residents, interest in creating community for social reasons outweighed environmental considerations as a motivating factor in relocating to the village (see also Kirby, 2003). Yet these communal activities that many residents value also appear to play a role in decreasing environmental impact. In fact, while environmental attitudes and behaviours existed among residents prior to moving to EcoVillage at Ithaca, it appears that these were further shaped and developed as part of this community.

The EF as a Planning Tool

In conducting this study, some limitations of the EF as a tool in urban planning and design were encountered, but also the utility of a tool that combines aspects of built form and consumption into an environmental assessment was identified. The first limitation relates to data. The total EF of a person, household or neighbourhood must necessarily include many different types of resource use, some of which are difficult to estimate at the disaggregate level (Mclean & Korol, 2004) and others for which data could be assembled, but at considerable cost. One of the most difficult categories to estimate at the local level is food consumption, in part because quantities are difficult to recall or estimate, but also because the origins of different foods are often unknown and the inputs to various food products are virtually impossible to estimate. Indeed, most of the data for food would necessarily come from self-reports, which are well known to have limitations in terms of accuracy and completeness (Hamilton, 1985; Newell *et al.*, 1999; Parslow *et al.*, 2003; Tucker, 2003). For transportation, municipal origin–destination data and vehicle registration data may be sufficient to derive accurate estimates of automobile travel at the neighbourhood level, but air travel would require additional survey work.

These data challenges raise an important question about which aspects of total consumption or resource use are most related to urban design and are thus worth considering. It would appear that physical layout and construction, utility use, automobile travel and even food consumption (for example, through provision of gardens or communal eating facilities in the case of EcoVillage) are all potentially affected by design. In addition, we did not consider goods consumption of any kind, and it would seem that dwelling size could also affect this category. Thus, further research is necessary to provide guidelines on how to efficiently and appropriately apply the EF at different scales for different purposes.

Related to the above discussion is the question about what factors planners in day-to-day practice should be measuring in the first place. It is arguably outside the planner's direct mandate to direct or constrain personal behaviour. However, as environmental issues move up on the political and public agenda, it will be important that the planning and design professions can establish their place in matters of sustainability. 'Good' planning begins with an assessment of users' needs (Leung, 2003). For example, transit stops are located in a way that is sensitive to demand. However, planning may also help to shape demand. Indeed, the very existence of planning reveals some general level of acceptance that land markets require guidance, and there is a growing sense that planners ought to have a right to ask people to change behaviour if they can prove that a present behavioural pattern or community arrangement is dangerous to the people concerned or to others (Gans, 1969). Environmental externalities may be the single most compelling argument against sprawl (Krieger, 2004). Suburban development has devoured many wetlands, for instance, with consequences for future water quality and supply (Draper, 1998; Pollard, 2001). Auto-dependence and associated air pollution have severe implications for those with respiratory problems, and carbon dioxide emissions may contribute to climate change with unforeseeable consequences.

Due to perceived threats from unconstrained growth, there has been an increasing trend towards the inclusion of environmental issues in decision making. Whether this trend is based on a real need, for example due to environmental scarcity and degradation, is a point of some discussion (see, for example, Gordon & Richardson, 1998; Daniels, 1999). Nonetheless, the increase in voluntary environmental initiatives (see Environmental Protection Agency (EPA), 2004), growth in green products/designs (see Global Eco-Labeling Network (GEN), 2004; Green Building Council (GBC), 2004) and the rising demand for alternative housing designs (Wilson *et al.*, 1998; Canadian Mortgage and Housing Corporation (CMHC), 2000a; Mayfield, 2000) demonstrate that environmental and social issues have a market value and are not solely issues imposed by regulation. In fact, the CMHC (2000b) identified regulatory and institutional processes as key barriers in the sustainable community development process. Ecovillages were often built without regulatory approval (Wilson *et al.*, 1998; Bowers, 2002), and new-urbanist principles are only now being incorporated into planning regulations (Duany, 1989; Berke *et al.*, 2003).

True-cost accounting reveals that unconstrained urban growth does indeed have negative economic, social and environmental impacts (Kelbaugh, 1997; Burchell *et al.*, 2002). The notion that substitution due to rising prices of scarce resources will solve environmental problems may well be based on incomplete knowledge of ecosystem functions. Nonetheless, the problem is likely not that human ingenuity and markets cannot find alternatives; markets and their supporting institutions may well just be too slow to adjust to promote widespread adoption of the alternative before ecosystems are irreversibly damaged, rendering them uninhabitable for human survival (Kay, 1991, 2002). Architects, planners and designers have devised various development alternatives to address concerns associated with urban sprawl. However, it is often a matter of adjusting the regulatory process and institutions to allow novel designs to proceed from ideas to practice. The EF may offer a tool to make the environmental potential of these communities more visible in decision making. Assessing the effects of both built form and consumption urges planners and designers to begin thinking about built form from an environmental consumption point of view.

A further justification for why planning and design research should consider impacts from both the built form and behaviour is due to substitutions effects that can occur. Indeed, many of the problems associated with sprawl, such as resource use from large single-family dwellings and automobile dependence, are perhaps just problems of an affluent, consumer-based society (Krieger, 2004). Certainly, one would expect demand for land and housing to increase with growing incomes (i.e. they are 'normal goods'). If these preferences are artificially removed through growth management, net environmental impacts will depend on how income is allocated. For example, if savings from the reduced commute and lower housing costs are spent on foreign travel or consumer goods, net effects on the environment may be either positive or negative. Hence, an understanding of how built form and lifestyle interact is required. The EF can provide such insight because it allows for an assessment of a full range of categories.

One inherent weakness of using the EF for this purpose is that it, like other inventory tools, is intended to measure impact. EF is not designed to get at cause and effect. However, where qualitative data provide insight into decision-making processes and choices, the EF becomes a useful tool for understanding the pathways to different outcomes. Also, the raw data assembled for its calculation could be used for specific questions of importance in planning practice, for example how much land is impermeable in different subdivisions, as illustrated for the case study.

Another aspect of EF that warrants discussion relates to the protection of environmentally significant features and natural processes when the site is developed. The EF is not well suited to this important issue. Instead of assessing what land to protect, the EF assesses the consumption of bio-productive land through materials consumed, i.e. it translates all consumption (e.g. land, materials used for roads, buildings, yards) into productive land equivalents. It is clearly a drawback at the site level if significant natural areas are only configured into the equation as land consumed. Thus, it would be important for EF analysis to be complemented with ecosystem planning approaches. However, because the EF asks the sustainability question from a consumption rather than a protection point of view, it does illustrate impact in a way that cannot be achieved by site-focused methods.

In addition, the EF could be used by policy makers as part of the approvals process for proposed developments. Rather than restricting development according to standard urban design codes, developments could be classified by a maximum EF. It would be up to developers and designers to plan communities that fall within the assigned EF. Rather than crippling innovation and creativity in urban design through legislation, a maximum assigned EF would foster new ideas and designs to tackle the sustainability challenge.

The EF tool would work well in this capacity as it aggregates land-use impacts and illustrates where trade-offs exist. The designer may decide to make streets narrower but increase housing size, or increase urban parks but decrease pathways, while still remaining within the overall desired EF. Designers may even go to the extent of trading permitted EF values; if one developer builds above the allowed EF, s/he could purchase additional EF capacity from a developer that built below the permitted EF value. In this sense, the system would operate much like a tradable permits system currently being implemented for numerous air pollutants. Transferable permits have long been used by local US governments to balance some of the attributes and amenities ordinarily addressed by zoning (Stavins, 2000). Furthermore, development and property taxes could be scaled, dependent on the EF of a subdivision, as an incentive to encourage more sustainable design practices. At minimum, calculating the EF of new developments would educate stakeholders on the environmental implications of different developments. As an analysis tool, EF incorporates life-cycle analysis in a manner that is "... intuitive and visually graphic ... for communicating one of the most important dimensions of the sustainability dilemma" (Walker & Rees, 1997, p. 99).

Conclusions

The findings presented here provide a first estimate of differences in the EF for various subdivision designs. Although more research is required to generalize the results, the findings show that denser designs in this study reduced the EF by more than one acre per person as compared to estate-style housing, due to differences in housing size, private lawns and parking. However, the study indicates that consumption, not built form, contributes most to the overall footprint; therefore, the link between design and behaviour is of critical importance. The experiences at EcoVillage at Ithaca suggest that physical design may be a catalyst or facilitator of some changes in consumption, especially as they relate to utilities and possibly also to transportation, but no overall conclusion on the interaction between design and behaviour can be drawn from this study. More research is therefore required to address how the way we build our cities influences consumptive behaviour. Nonetheless, the data show that planners and urban designers need to begin thinking about environmental impacts in more holistic terms, and the paper provides an example of how this can be done. While ecovillages represent a departure from the norm that is too large to suggest that specific findings would have application to mainstream society, insights into the degree, and pathways, of difference in consumption between neighbourhoods of different designs provides a starting point for serious dialogue on the need for holistic environmental assessment at the design stage.

In addition, the study illustrates that EF could play a useful role in conducting such assessments, by documenting some of the behaviours that are most crucial to a person's total environmental impact and how they are related to design and built form. The EF tool was deemed to have considerable promise as a neighbourhood planning tool, despite challenges associated with data assembly and conversion and limitations in its ability to deal with cause-and-effect processes.

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